Task 2: Conceptual Models

Background

As detailed in the Provisional Indicators Scoping Document, the creation of Conceptual Models (CMs) for the Puget Sound ecosystem is one of four tasks to be undertaken in an effort to select provisional environmental indicators for the Puget Sound Partnership (PSP). The CMs are meant to serve three purposes. First, the process of developing the CMs that define the key components, structures, and functions and mechanisms of the Puget Sound ecosystem should serve to create a common knowledge base among the scientists that will be selecting the initial list of provisional indicators. This common knowledge should help scientists from multiple disciplines to make educated decisions when selecting provisional indicators for Puget Sound. Secondly, these CMs will be used as a tool to communicate these key structures and functions to managers and the public, thus allowing better connections between science and policy. Finally, conceptual models can be used to identify how an individual indicator is likely to respond to ecosystem changes as well as known or assumed relationships among indicators (NRC 2000).

The Provisional Indicators Technical Working Group (TWG) decided that conceptual models were needed for each of the ecosystem components set by the PSP: water quality, water quantity (freshwater only), species, habitats, human health, and human well being. Recognizing the inter-connections among these components, the TWG members decided that all of the conceptual models should feed into the existing whole-ecosystem based conceptual model that is currently being used by the PSP (Figure CM1). These component-based conceptual models would provide more detail and substance for the relatively simplistic whole ecosystem based model of Puget Sound (Figure CM1). Narrative goals for each ecosystem component (see 2006 Partnership Sound Health Sound Future) were used as guiding principals to scope the component-based CMs.

Collectively, TWG conceptual model sub-group decided to develop 15 CMs (Table CM1). Given the short time frame to develop CMs, simple schematics with just text and lines were developed. Additional resources will be necessary to complete enhanced conceptual diagrams with informational rich graphics suitable for communicating with managers and the public (Dennison et al. 2007).

The conceptual model sub-group also recognized the need for more narrowly defined conceptual models specific to subsets of indicators that will be monitored within each of these ecosystem components. However, it was decided that this work would be have to take place after the draft provisional indicators were identified.

Table 1. Conceptual Models proposed by the Provisional Indicators Technical Working Group. Bolded X indicates the a draft CM has not yet been completed.

Ecosystem Component	Ecosystem Sub-Component	Marine Areas	Freshwater Areas	Terrestrial Areas
Water Quality	Toxics	X	X	
	Nutrients	X	X	
	Pathogens	X	X	
Water Quantity		X	X	
Species		X	**X**	**X**
Habitats		one generic model		
Human Health		3 individual models specific to individual stressors/ pressures (toxics, nutrients, pathogens)		
Human Well Being		one generic model		

Structural Framework for Ecosystem Component-Based CMs
A Driver- Pressure-State-Impact-Response (DPSIR) Framework (Niemeijer and de Groot 2008; Pirrone et al. 2005) was chosen as the common framework to develop the various component-based conceptual models. The DPSIR framework clearly defines the causal links or relationships between ecosystem attributes we can measure and aspects of the ecosystem that have high relevance to humans (i.e. potential indicators for the Action Agenda). Specifically, the DPSIR framework defines the causal links between human activities (i.e. drivers), the stress or pressures they can put on the ecosystem, that cause changes in the state of ecosystem components, resulting in negative impacts to other ecosystem components. Ultimately, society can react (i.e. show a response), often with management actions that can regulate the driver, the pressure, state, or impact.

Two existing whole-ecosystem CMs developed for Puget Sound, the PSAMP Conceptual Model (Newton et al. 2000) and the Puget Sound Nearshore Partnership Conceptual Model (Simestad et al. 2006) were evaluated by the TWG to see if they could be modified to fit the DPSIR Framework. Both of these Puget Sound CMs were developed with broad consensus from local scientists. By using a common framework and input conceptual models and terminology, the CM sub-groups should generate CMs that readily link together.

PSAMP Conceptual Model
The PSAMP CM details linkages between human activities that create multiple stressors to the ecosystem and the specific ecosystem components potentially altered by those stressors. Management actions linked to activities that produce the stressors are also detailed as well as natural mechanisms and inputs that affect the ecosystem. The terminology in the PSAMP CM was converted to the

DPSIR terms as follows: Activities = anthropogenic Drivers; Natural Mechanisms = natural Drivers; Inputs into Puget Sound = external Drivers (for marine waters) that modify Stressors; Stressors = Pressures; Components Affected = States and Impacts; and Management = Response.

Although the PSAMP CM provides a comprehensive set of information about the ecosystem, it has some limitations for use within a DPSIR framework. First, the PSAMP CM focuses only on the marine components of the ecosystem so it may not be applicable to freshwater and terrestrial regions of Puget Sound. Users of the PSAMP model will have to modify the ecosystem components to include freshwater and terrestrial attributes. Second, although the PSAMP CM specifies which specific elements of marine ecosystem are affected, it does not indicate state versus impact attributes. For example, anthropogenic drivers (activities) that result in an increased pressure (stressor) of toxics to the ecosystem are linked to changes in fish but the PSAMP model does not indicate how the state of fish are altered (i.e. increased toxics body burdens) or the potential or known impacts (e.g., immunosuppression or reduced growth). Thus, to use the DPSIR framework with the PSAMP CM, documented impacts (with associated citations) will need to be added to the details extracted from the PSAMP CM. Third, the expertise of the TWG must be used to detail the processes underlying ecosystem changes as this information is lacking from the PSAMP CM. Finally, as detailed below, the PSAMP CM cannot be used to develop the species component-based models because food web linkages are not built into the model. Nor can the PSAMP CM be used to create a human well being CM as attributes of human well-being are not included in the model.

The PSNERP Conceptual Model

The PSNERP CM was developed to aid in the assessment of restoration and preservation measures for the nearshore of Puget Sound. The model is best used to elucidate nearshore processes, and the response of the nearshore ecosystem to actions causing stress or actions associated with restoration. The model was designed to depict how the Puget Sound nearshore ecosystems work, and as such it details how hydrological, geomorphological, and ecological processes can sustain or impair important nearshore structures, that provide ecosystem goods, services and functions. Due to its complexity, translating the details of the PSNERP model into a DPSIR framework proved too difficult. However, process discussed in the PSNERP model (e.g. hydrological, geomorphological, and ecological processes) are include in our CMs..

DPSIR modified PSAMP CM: Standard Color Scheme and Layout

As detailed below, the TWG decided that the PSAMP conceptual, modified to fit the DPSIR framework, could be used for all the ecosystem component CMs, except for human well being. Measures of human well-being were not included in the PSAMP conceptual model but are developed separately for the human well being CM (see below). The DPSIR modified model addressed the limitations with the PSAMP model and included process/ functions noted in the PSNERP model.

A standardized color scheme and layout was used for all DPSIR modifies PSAMP CMs. Drives are not in browns boxes, pressures in cyan boxes, states in pink ovals, impacts in red ovals and responses in green boxes. Specific societal or management responses were not shown, however, the habitat CM does include categories of actions that could be undertaken. Within each ecosystem component CM, white boxes denote links to other ecosystem component CMs under development.

Water Quality CM

TWG sub-group included Julia Bos, David Hallock, Lynn Schneider, and Maggie Dutch from Ecology, Curtis DeGasperi and Kim Stark from King County, Jim West from WDFW, and Claudia Bravo and Sandie O'Neill from NOAA Fisheries.

A DPSIR-modified PSAMP CM was uses to track specific drivers/ pressures of water quality to state and impacts for specific species groups and to human health. Based on the Partnership water quality goals, only pressures related to toxics, nutrients and pathogens were considered. "Water quality" issues associated with such things as silt inputs will be dealt with in the habitat CM. To date, marine and fresh water CMs have been developed for toxics (Figure WQL 1 and Figure WQL 2) and nutrients (Figure WQL 3, Figure WQL 4). A generic CM for pathogens been developed (Figure WQL5) and eventually will be split into marine and freshwater models.

The "activities" listed in the PSAMP CM, termed anthropogenic drivers for the DPSIR framework, were initially re-grouped into sources and their associated conveyance systems (pathways). **However, the TWG could not reach consensus on what was a driver and what was a pathway. Currently, stormwater and runoff etc. are not listed consistently as a source or a pathway.** Some impacts to the ecosystems have been added, however, additional ones may be needed.

Water Quantity CM

TWG sub-group included Curtis DeGasperi from King County, Mark Mastin from USGS and Claudia Bravo and Sandie O'Neill from NOAA Fisheries

Figure WQT 1 is a draft CM for freshwater quantity. Additional work is needed as detailed below:

- Separate and clarify individual impacts into separate ovals indicate link to other relevant conceptual models. [Would need larger format and more time for this next level of detail. Suggest single group to further improve and integrate the various models developed as part of this process.]

- Need to add arrow indicating linkages between freshwater flows and inflow to Puget Sound. [Not sure how to accomplish this within existing format. Suggest this as additional refinement as part of integration of conceptual models.]

- Based on comments from Water Quality Subgroup on Marine Circulation conceptual model, it appears that they would prefer “Altered Biological Communities”, “Water Quality Changes”, and “Altered Riparian and Wetland Communities” to be moved from States to Impacts. [Suggest single group to further improve and integrate the various models developed as part of this process, including consensus on what constitutes a State or Impact.]

Potential Management Options that could be listed in the Response box include: land use controls for stormwater, best management practices/low impact development for stormwater control, source exchange (e.g., reclaimed water for groundwater withdrawals, in-stream flow goals, water rights management, prevent loss of and restore riparian/flood plain/wetland functions, natural flow regime concepts for river management, water conservation/use efficiencies, and protect farm and forest uses while improving management practices.

Figure WQT 2 is a draft CM for marine water circulation. Additional work is needed as detailed below:

- From Water Quality (WQL) Subgroup: Add arrows/text to identify links from impacts to other conceptual models. [Would need larger format and more time for this next level of detail. Suggest single group to further improve and integrate the various models developed as part of this process.]

- From Water Quality (WQL) Subgroup: Remove original aggregated Impact bubble.

- From Water Quantity (WQQ) Subgroup: Separate and clarify individual entries in impacts oval to indicate link to other relevant conceptual models. [Similar comment from WQL subgroup. Would need larger format and more time for this next level of detail. Suggest single group to further improve and integrate the various models developed as part of this process.]

Species CM

TWG sub-group included Glenn Merritt from Ecology, Jim West and Scott

Pearson from WDFW, and Chris Harvey, Correigh Greene, Claudia Bravo and Sandie O'Neill from NOAA Fisheries.

Theoretically at least, water quality, water quantity, and habitat CMs should all show links from the drivers (activities) that cause pressures that affect species groups. These water quality, water quantity, and habitat CMs should also highlight the drivers for natural processes that impact species growth, reproduction, and survival. As such, the species CM only had to map those drivers that affected species directly (e.g. harvest, hatcheries, aquaculture, and activities that increase or decrease invasive and "exotic" species).

A generic species CM was created for marine, freshwater and terrestrial systems (see Species slides show). Guideline for using this model are noted below:

- This is not an ecosystem models: DPSIRs model the impacts of various "drivers" on ecosystem components
- The rFood Web DPSIRs are a small subset of the drivers effecting marine food webs (see habitat, water quality, water quantity, etc.)
- Other DPSIR models have only indicated the population level impacts and not the community level impacts.
- The positive human effects of the drivers that follow are captured in the "human well being" model.
- The actual effects of the following drivers will depend on the magnitude of pressure and type of pressure.

Next steps include modifying the generic CM for species functional groups for marine, freshwater and terrestrial habitats. The general framework for selecting species functional groups was to categorize species by trophic status and position (e.g. benthic, pelagic, surface orientated etc.) and possibly some attributes of mobility. For the marine food web, this matrix was compared against other classification efforts in the region (e.g. South Sound Eco-path, Sound Science, PSAMP, and the current risk analysis by Mary Ruckelhaus's group). The freshwater species functional groups also used this framework, with additional other local food web efforts. Currently, the Species Slide Show details the 22 functional groups only for the marine species.

Habitat CM

TWG and SC sub-group included Glenn Merritt from Ecology, Scott Pearson, Jim

West, and Curtis Tanner from WDFW, Tom Mumford and Helen Barry from DNR, and Chris Harvey, Correigh Greene, Erin Richmond, Claudia Bravo and Sandie O'Neill from NOAA Fisheries. Additional input was provided by WDFW staff: Tim Quinn, John Pierce, Marc Hayes, Gail Olson, Matt Vander Haegen, and George Wilhere.

To date we have developed a generic Habitat CMs. Substantially more time will be needed to detail how specific drivers or pressures affects habitat in both watersheds and marine. This model assumes:

Habitat states can be changes to processes (physical/hydrological, biotic, energy, chemical) and/or changes to structure (habitat types and their connectivity).

Type of impacts to habitats result in changes to species and their food webs and
ecosystem services (e.g., flood control, water filtration, carbon storage).

Water moves downhill, so freshwater processes can influence marine processes and structure, but not vice versa (except through food webs)

In the generic habitat CM, freshwater, estuarine and marine habitats are combined into one conceptual model. Watershed processes (includes freshwater and terrestrial) and marine processes (depicted as mirrored images) intersect in the estuary/shoreline, as do their food webs and ecosystem services (Figure HB1). Processes within systems influence the structure. When dealing with processes and structure, the estuary/shoreline is lumped with marine systems. Freshwater processes can affect freshwater structure but they can also affect marine processes and structure.

Anthropogenic drivers can cause pressures that can influence either processes or structure, and when they influence structure, structure changes in state (e.g., old growth to second growth). "Natural" drivers and external drivers (e.g., climate change) are listed as "Natural/Anthro" because climate change can be modified by anthropogenic activities. Each driver has specific pressures that affect habitat processes or structure, in either watershed or marine systems.

Structures are defined by both quantity (amount of habitat x as it is modified to habitat z (e.g., amount of eelgrass changing to mudflat) and connectivity, but also by quality which the model assumes is the variable influence of process on structure.

Links to other ecosystem component-based CMs are noted as white boxes. Thus, hydrologic processes and their consequences are part of the Water Quantity CM, and chemical environment. Processes also link to Water Quality CM.

Within each system, impacts to habitat structure and processes affect species and their respective food webs, depicted as overlapping circles, to indicate that watershed and marine food webs overlap. Small arrow indicates that certain species (e.g., salmon) move between food webs at different stages of their life cycle. Impacts to habitat can also affect ecosystem services (e.g., water storage, water filtration, carbon storage).

Logical links among states and impacts are noted. For example, both habitat processes and structure influence both food webs and ecosystem services but there may be some feedback loops (hence, double arrowed lines). Also, species and food webs can influence ecosystem services. Again, white boxes indicate links to and from the species CM(s).

Impacts to food webs and ecosystem services then create a societal response, which includes management. Within the RESPONSE box, a list of action verbs are listed to denote how society might respond to, drivers, and pressures, states and impacts. These action verbs are meant to actions that might be undertaken, not who is doing the actions – restoration activities can be done by private citizens, NGOs, and the government. Societal responses are connected to human health and well being, noted as links to the human health and well being CMs, and link back to the drivers.

<u>Human Well Being</u>

The human well being (HWB) sub-groups included Jessica Archer from Ecology, Dave McBride, Joan Hardy and Tim Determan from the Department of Health, Rachel Water from Sea Grant,) and Morgan Schneidler and Marc Plummer, Claudia Bravo and Sandie O'Neill from NOAA Fisheries.

Neither the PSAMP CM, nor any other model currently used in Puget Sound, explicitly addresses attributes of human well-being. Thus, in an effort to create a comprehensive list of the multiple attributes of human well-being, (i.e., potential HWB indicators) related to the health of Puget Sound, the work group used matrices to compare goals for human well being with goals for the other ecosystem components. To date, all of the ecosystem component-goal matrices have been completed and a potential list of HWB indicators has been developed.

A Human well being CM has been developed (see attached slide show) for a complete description. The proposed human well being CM has two major categories, externality and sustainable use.

<u>Externality</u>:

This example acknowledges that there are externalities that affect various ecosystem components while contributing intentionally to an aspect of human well being. In this example human well being is seen on either end of the Driver-Pressure-State and Impact aspect of the ecosystem components conceptual models. The response is divided into two categories, one intentional (in which management targets the externalities) and one unintentional (in which management targets the activity itself (i.e. reduction of the activity) which ultimately reduces HWB).

<u>Sustainable Use</u>:
This is similar to what we were originally calling a “two way” example.   In this an activity which increases human well being in the short run can also unintentionally decrease human well being in the long run by adversely affecting ecosystem components. In this example response must differentiate between the short run human well being (Human well being goes down as activity goes down) and long run (human well being increases in the long run as the ecosystem health increases).

Examples are given on slides #6 and #7 of the slide show. Here we emphasized species but also recognize as affects become more complicated so too are the human well being affects. Other activities can affect the same chain.

In our example if you cut back those other activities then the harvest levels may not need to change. This is shown in slide #8

Slide 9 and 10 provide a bit more about HWB and ecosystems to assist with thinking through the sustainable use example.

Slide 11 is the indicator uses slide showing the spectrum of indicators which may be needed to understand the system.

<u>Human Health</u>
The human health (HH) CM sub-groups included Jessica Archer from Ecology, Dave McBride, Joan Hardy and Tim Determan from the Department of Health, Rachel Water from Sea Grant, Heather Trim from People for Puget Sound and Morgan Schneidler, Claudia Bravo and Sandie O’Neill from NOAA Fisheries.

A DPSIR-modified PSAMP CM was somewhat useful for development of a CM for the human health ecosystem component, as the PSAMP CM detailed links between stressors (i.e., pressures) and human health by two major exposure pathways, dermal contact and ingestion. Exposure pathways via inhalation were not explicitly detailed in the PSAMP CM but are included in the PSP goals. Thus, in an effort to create a comprehensive model for human health that included all pathways pertinent to the PSP goals, the work group used matrices to compare goals for human health with goals for the other ecosystem components. These ecosystem component-goal matrices helped to better define the multiple attributes of human health (i.e. things to be measured) that need to be included in the human health CM. Where possible, the PSAMP CM, modified to fit the DPSIR framework, will be used map the drivers and pressures that affect the human health attributes identified in the matrices. Human health attributes not included in the PSAMP CM added to the CM by group consensus.

DPSIR human health models have been completed for toxics (Figure HH 1), nutrients (Figure HH 2), pathogens (Figure HH 3), and bio-toxins (Figure HH 4).

NEXT STEPS

Conceptual model needed to be linked using asome sort of web-linked CM or a program like Personal Brain.

Terms must be defined and be used consistently throughout all CMs.

Create summaries of the key information to feed into the CMs (e.g. spreadheet or word documents).